CLAIMS

We claim:

1. A qubit system, comprising:

   a qubit, the qubit including a multi-terminal junction coupled to a superconducting loop, the superconducting loop having a phase shift; and

   a controller coupled to the qubit.

2. The system of Claim 1, wherein the multi-terminal junction includes at least one constriction junction.

3. The system of Claim 1, wherein the multi-terminal junction includes at least one tunnel junction.

4. The system of Claim 3, wherein the tunnel junction is formed by an insulating layer separating two of the at least two terminals.

5. The system of Claim 4, wherein the two of the at least two terminals are an s-wave superconducting material.

6. The system of Claim 1, wherein the multi-terminal junction includes at least one two-dimensional electron gas structure.

7. The system of Claim 6, wherein the at least one two-dimensional electron gas structure is an InAs layer deposited on an AlSb substrate.

8. The system of Claim 1, wherein the superconducting loop includes a first portion of a s-wave superconducting material and a second portion of a s-wave superconducting material and wherein a portion of the phase shift is produced by a d-wave superconducting material coupled to the first portion

and the second portion through normal metal interfaces, the portion of the phase shift being determined by the angle between the normal metal interface and crystallographic directions in the d-wave superconducting material.

9. The system of Claim 1, wherein the superconducting loop includes a first portion of a s-wave superconducting material and a second portion of a s-wave superconducting material and wherein a portion of the phase shift is produced by a first d-wave superconducting material coupled through a normal metal to the first portion and a second d-wave superconducting material coupled through a second normal metal to the second portion, the portion of the phase shift being determined by the difference in crystallographic directions in a grain boundary interface between the first d-wave superconducting material and the second d-wave superconducting material.

10. The system of Claim 9, wherein the first d-wave superconducting material and the second d-wave superconducting material are formed on insulating crystals.

11. The system of Claim 9, wherein the s-wave superconducting material is chosen from a group consisting of Aluminum, Niobium, Lead, Mercury, and Tin.

12. The system of Claim 9, wherein the d-wave superconducting material is $YBa_2Cu_3O_{7-x}$.

13. The system of Claim 10, wherein the insulating crystals can be chosen from the group consisting of Strontium Titanate, Sapphire, Cerium Oxide, and Magnesium Oxide.

14. The system of Claim 1, wherein a portion of the phase shift is produced by a ferromagnetic junction.

15. The system of Claim 14, wherein the superconducting loop includes a first portion and a second portion, the first portion and the second portion being coupled by the ferromagnetic junction.

16. The system of Claim 15, wherein the first portion and the second portion are each s-wave superconducting material.

17. The system of Claim 16, wherein the s-wave superconducting material is chosen from the group consisting of Aluminum, Niobium, Lead, Mercury, and Tin.

18. The system of Claim 16, wherein the ferromagnetic junction is formed by copper or Nickel sandwiched between the first portion and the second portion.

19. The system of Claim 16, wherein the ferromagnetic junction is provided by implanting a ferromagnetic material into the s-wave superconducting material between the first portion and the second portion.

20. The system of Claim 1, wherein the superconducting loop is formed from a d-wave superconducting material and wherein a portion of the phase shift is formed by grain boundaries in the d-wave superconducting material of the superconducting loop.

21. The system of Claim 1, wherein the controller is coupled to terminals of the multi-terminal junction to provide transport current through the multi-terminal junction.

22. The system of Claim 1, wherein the controller can pass current symmetrically through the multi-terminal junction.

23. The system of Claim 22, wherein the controller can perform a σ_x phase gate operation on the qubit by applying a pulse of current symmetrically through the multi-terminal junction.

24. The system of Claim 22, wherein the controller can tune the qubit by applying a constant current symmetrically through the multi-terminal junction in order to adjust a tunneling frequency between quantum states of the qubit.

25. The system of Claim 24, wherein the controller tunes the qubit so that the tunneling frequency of the qubit substantially matches tunneling frequencies of other qubits in a qubit array.

26. The system of Claim 1, wherein the controller can pass current asymmetrically through the multi-terminal junction.

27. The system of Claim 26, wherein the controller can initialize the qubit by passing current asymmetrically through the multi-terminal junction for a sufficient amount of time that a quantum state of the qubit becomes a preferred state.

28. The system of Claim 27, wherein the controller can initialize a first quantum state by applying an initialization current asymmetrically through the multi-terminal junction in a first direction and can initialize a second quantum state by applying current asymmetrically through the multi-terminal junction in a second direction opposite the first direction.

29. The system of Claim 26, wherein the controller can read a quantum state of the qubit by applying a read current asymmetrically through the multi-terminal junction and measuring a voltage across the multi-terminal junction.

30. The system of Claim 29, wherein the read current is greater than a critical current of the junction associated with a first state and smaller than a critical current of the junction associated with a second state, wherein measurement of the voltage across the multi-terminal junction indicates the first state and absence of the voltage across the multi-terminal junction indicates the second state.

31. The system of Claim 26, wherein the controller can perform a σ_z phase gate operation by applying a pulse of current asymmetrically through the multi-terminal junction.

32. The system of Claim 1, wherein an external magnetic field can be applied to the superconducting loop.

33. The system of Claim 32, wherein a phase gate operation can be performed by application of the external magnetic field.

34. The system of Claim 32, wherein the external magnetic field provides the phase shift in the superconducting loop of the qubit.

35. The system of Claim 1, further including a readout for reading a quantum state of the qubit.

36. The system of Claim 35, wherein the readout includes a radio-frequency single electron transistor electrometer.

37. The system of Claim 35, wherein the readout includes a magnetic force microscope.

38. The system of Claim 35, wherein the readout includes a superconducting loop.

39. The system of Claim 35, wherein the readout includes a Hall probe.

40. The system of Claim 1, further including a second qubit, the second qubit coupled to the first qubit through an entanglement junction.

41. The system of Claim 40, wherein the entanglement junction includes a multi-terminal junction and a plate in proximity with the multi-terminal junction.

42. The system of Claim 41, wherein the plate capacitively couples a voltage into the multi-terminal junction of the entanglement junction.

43. The system of Claim 41, wherein the plate is coupled to the controller so that the controller can switchably entangle the quantum states of the qubit and the second qubit.

44. The system of claim 41, wherein the multi-terminal junction of the entanglement junction is separated from the superconducting loop of the qubit.

45. The system of Claim 41, wherein the multi-terminal junction of the entanglement junction includes a two-dimensional electron gas junction.

46. The system of Claim 41, wherein the multi-terminal junction of the entanglement junction includes a tunneling junction.

47. The system of Claim 41, wherein the multi-terminal junction of the entanglement junction includes a constriction junction.

48. The system of Claim 1, wherein the multi-terminal junction is a 3 terminal junction.

49. The system of Claim 1, wherein the multi-terminal junction is a four-terminal junction.

50. The system of Claim 1, wherein the multi-terminal junction is a five-terminal junction.

51. The system of Claim 1, wherein the multi-terminal junction is a six-terminal junction.

52. The system of Claim 1, wherein the multi-terminal junction includes more than six terminals.

53. The system of Claim 1, wherein the qubit is coupled to other qubits to form a qubit array.

54. The system of Claim 53, wherein the multi-terminal junction of the qubit is shared with other qubits of the qubit array.

55. The system of Claim 53, wherein the multi-terminal junction of the qubit is coupled to multi-terminal junctions that are not included in other qubits.

56. The system of Claim 1, wherein the qubit is coupled to other qubits to form a random number generator.